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Frictional performance evaluation of newly designed brake pad materials

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ABSTRACT

This work is aimed to study the tribological properties difference of potentially new designed non-commercial brake pad materials with and without asbestos under various speed and nominal contact pressure. The two fabricated non-commercial asbestos brake pad (ABP) and non-asbestos brake pad (NABP) materials were tested and compared with a selected commercial brake pad (CMBP) material using a pin-on-disc tribo-test-rig under dry contact condition. Results showed that friction coefficients for all materials were insensitive to increasing speed and pressure. NABP maintained stable frictional performance as ABP material when contact temperature elevated. Moreover, NABP proved to have greater wear resistance compared to ABP and CMBP materials. Furthermore, the SEM micrographs of brake pad surfaces showed craters which is due to disintegration of plateaus. Finally, the test results indicated that the NABP has the potential braking characteristic for a brake pad material.

1. Introduction

The brake system is a very important component to vehicles and machinery equipment in industries. Nowadays, most vehicles use disc brakes as they dissipate heat better hence reducing fade when compared to drum brakes [1]. The rotor disc materials of a disc brake system are normally made from gray cast iron due to its excellent heat conductivity, good damping capacity and high strength [1–3]. Brake pads convert the kinetic energy of the car to thermal energy by friction. When the brake pad is heated up by coming into contact with the rotor disc to provide stopping power, it starts to transfer small amounts of friction materials to the disc or pad. However, in a disc brake system, there is no single material which has been able to meet the desired performance-related criteria such as safety and durability under various brake conditions [4]. The friction materials are required to provide a stable coefficient of friction and a low wear rate at various operating speeds, pressures, temperatures, and environmental conditions [4–7]. Furthermore, these materials must also be compatible with the rotor material in order to reduce its extensive wear, vibration, and noise during braking [4].

In the past two decades, asbestos was a popular ingredient used to produce brake pads, due to its strength, resistance to heat and fire-proof. Since 1980s, asbestos was known as harmful content and was banned from being used as an ingredient to produce brake pads, because it can cause lung cancer and other health problems. Therefore, non-asbestos contents like, Kevlar (aramid fiber), glass fiber, and graphite were used to replace the asbestos [8–10]. More than 10 different constituents are usually contained in a frictional brake pad material [4,7,11–14]. These constituents often contain binder resin, reinforcing fibers, solid lubricants, abrasives, wear resistance and other friction modifiers [4,5,7,11,12,14]. The type and amount of these ingredients are determined mostly based on experience, empirical observation [4,7], or a trial and error method to make a new formulation [15].

Binder resin and reinforcing fibers used in friction materials have substantial influence in determining the friction characteristics. Frictional heat generated during the brake application can easily raise the temperature at the interface beyond the glass transition temperature of the binder resin resulting in an abrupt change in the friction force during braking [4]. This occurs because of degradation of binder resin and other constituents. Fade resistance is a phenomenon that describes decreasing of friction force at high interface temperature, i.e. friction force decreases due to the frictional heat. Therefore binder resin is usually preferred to be heat resistant. For improved physical strength and friction performance, the friction materials usually contain two or three different fibers from metallic, ceramic, glass, acrylic, and other fiber [4,13].

The current work aims to evaluate and investigate the tribological properties of the two potentially new fabricated non-commercial brake pad materials (non-asbestos brake pad material – NABP and asbestos brake pad material – ABP), and comparing them with a non-asbestos commercial brake pad material – CMBP. The friction materials were characterized by measuring their hardness and ultimate compression stress. Tribo tests were carried out using a pin-on-disc type tribo-test machine. All the friction materials were tested against a gray cast iron rotor disc. The tests were conducted under the effects

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of nominal contact pressures (0.272–1.631 MPa), sliding speeds (2–20 m/s), and sliding distance (up to 42 km).

2. Experimental work

2.1. Preparation of pad specimens

In the present work, the fabricated non-asbestos brake pad material (NABP) and asbestos brake pad material (ABP) are compared to a commercial non-asbestos brake pad material (CMBP). The NABP and ABP materials comprise fiber reinforcement, friction modifiers, solid lubricant, abrasive, binders, and fillers. The formulations of NABP and ABP are similar except that there is asbestos fiber (10%) inside the ABP. However, in NABP, the asbestos fiber was replaced by a type of binder, Styrene Butadiene Rubber (SBR) with the same volumetric amount of 10%. As for the main categories, both materials consist of metal fiber (15%), friction modifier (16%), solid lubricant (8%), abrasive (3%), and the balance are phenolic resin and fillers. The relative amounts and type of non-commercial brake pads are given in Table 1. The friction materials were manufactured by dry-mixing, pre-forming, hot press molding at 2650 psi and 195 °C, post-curing, and heat treatment. All the brake pad materials were cut into specimen size of 9.5 mm × 9.5 mm × 20 mm, Fig. 1.

Table 1
The ingredients of the non-commercial brake pad materials (vol.%).

Raw materials	Sample code (Vol.%)	
	ABP	NABP
Asbestos fiber	10	–
Metal fiber–steel fiber	15	15
Friction modifiers–brass, cashew dust	16	16
Solid lubricant–graphite (C)	8	8
Abrasive–zircon ($ZrSiO_4$)	3	3
Binder (matrix)		
Phenolic resin	20	20
Styrene butadiene rubber (SBR)	–	10
Fillers, reinforcements	28	28

Fig. 1. (a) Prepared frictional brake pad specimens and (b) specimen dimensions.

Fig. 2 shows the microstructure of the polished cross sectional surface of all the brake pad materials. From the figure, it is clear that, the styrene butadiene rubber (black phases) can be seen in NABP (Fig. 2a) while absent for ABP (Fig. 2b). In addition, the distribution of brass fiber (large shiny element) and steel fiber (thin shiny element) of NABP and ABP can be seen clearly from Fig. 2a and b. On the other hand, CMBP contains high percentage of steel fiber surrounded by phenolic resin (dark phases), Fig. 2c.

2.2. Hardness and compression tests

In order to ensure uniform mixing and proper curing of brake pad during manufacturing, surface hardness of all brake pad materials were measured using Brinell hardness tester (Gunt Hamburg Universal Material Tester WP300) with 2 kN load and 10 mm diameter of indenter steel ball. Three repeated tests were conducted for each specimen and the average value is displayed in Table 2. Compression tests were also conducted using the same universal material tester for all three types of brake pad materials to obtain the ultimate compressive stress. Each specimen of 190 mm^2 in cross sectional area was tested. When the applied load came to the breaking point of the material, about 20% more of the load is applied to break the specimen. Three replications of compression tests were made for each material and the mean values are shown in Table 2.

2.3. Counter disc material

In the present work, grade-4E gray cast iron is selected as counter disc material. The chemical composition of the gray cast iron is given in Table 3. The initial average surface roughness (R_a) of 1.266 μm of gray cast iron disc was measured using Perthometer S2 and Stylus instrument. The surface hardness of the disc was in the range of 189.53 ± 6.20 HV_{30kgf} (Vickers Hardness Tester 430/450 SVA, Wilson Wolpert).

Table 2
Physical properties of non-commercial and commercial brake pad materials.

Raw materials	Specimen code		
	NABP	ABP	CMBP
Brinell hardness (HB)	19.03 ± 1.80	24.25 ± 2.12	16.02 ± 1.80
Ult. comp. stress (MPa)	60.53 ± 16.22	98.25 ± 19.10	84.21 ± 9.84

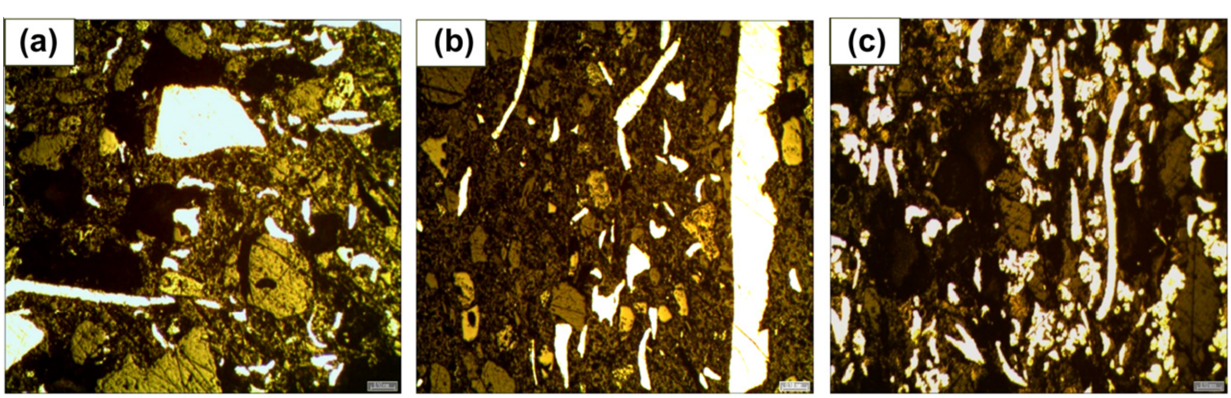

Fig. 2. Microstructure of brake pad materials (a) NABP, (b) ABP, and (c) CMBP.